US 20100242111A1

(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2010/0242111 A1

Kraemer et al. (43) Pub. Date: Sep. 23, 2010

(54) METHODS AND APPARATUS PROVIDING COMPUTER AND NETWORK SECURITY UTILIZING PROBABILISTIC POLICY REPOSTURING

(76) Inventors: **Jeffrey A. Kraemer**, Wellesley, MA (US); **Andrew Zawadowskiy**, Nashua, NH (US)

Correspondence Address:
HICKMAN PALERMO TRUONG & BECKER, LLP
2055 GATEWAY PLACE, SUITE 550
SAN JOSE, CA 95110 (US)

(21) Appl. No.: **12/789,339**

(22) Filed: **May 27, 2010**

Related U.S. Application Data

(63) Continuation of application No. 11/415,022, filed on May 1, 2006.

(60) Provisional application No. 60/751,439, filed on Dec. 16, 2005.

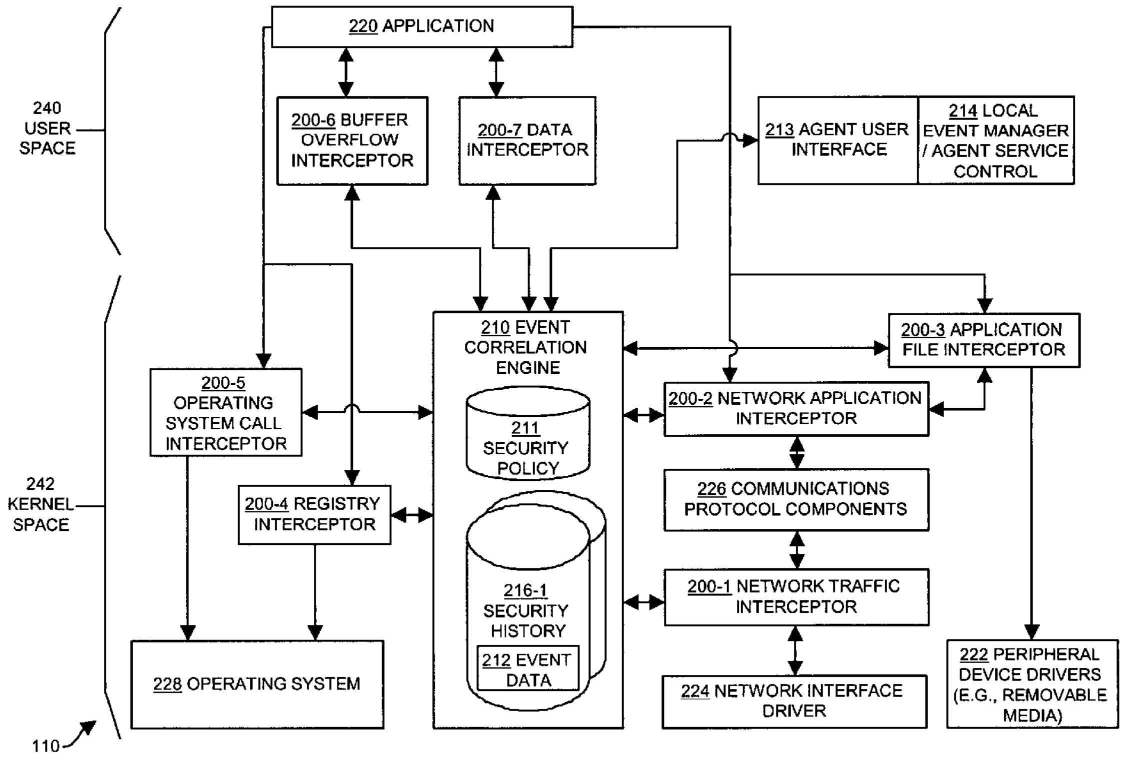
Publication Classification

(51) **Int. Cl.**
G06F 21/00 (2006.01)

(52) **U.S. Cl.** **726/22**

(57) **ABSTRACT**

A system defines at least one key event to be monitored by at least one agent, and creates a graphical model for the at least one key event. The system observes the at least one key event. The system infers a degree of attack on the computer system based on an observation of the at least one key event in conjunction with a result of an effect the at least one key event has on the graphical model. The system then adjusts a security policy based on an output of the graphical model.


220 APPLICATION
240 USER SPACE
200-6 BUFFER OVERFLOW INTERCEPTOR
200-7 DATA INTERCEPTOR
213 AGENT USER INTERFACE
214 LOCAL EVENT MANAGER / AGENT SERVICE CONTROL
242 KERNEL SPACE
210 EVENT CORRELATION ENGINE
211 SECURITY POLICY
216-1 SECURITY HISTORY
212 EVENT DATA
200-3 APPLICATION FILE INTERCEPTOR
200-5 OPERATING SYSTEM CALL INTERCEPTOR
200-2 NETWORK APPLICATION INTERCEPTOR
200-4 REGISTRY INTERCEPTOR
226 COMMUNICATIONS PROTOCOL COMPONENTS
200-1 NETWORK TRAFFIC INTERCEPTOR
228 OPERATING SYSTEM
224 NETWORK INTERFACE DRIVER
222 PERIPHERAL DEVICE DRIVERS (E.G., REMOVABLE MEDIA)
110

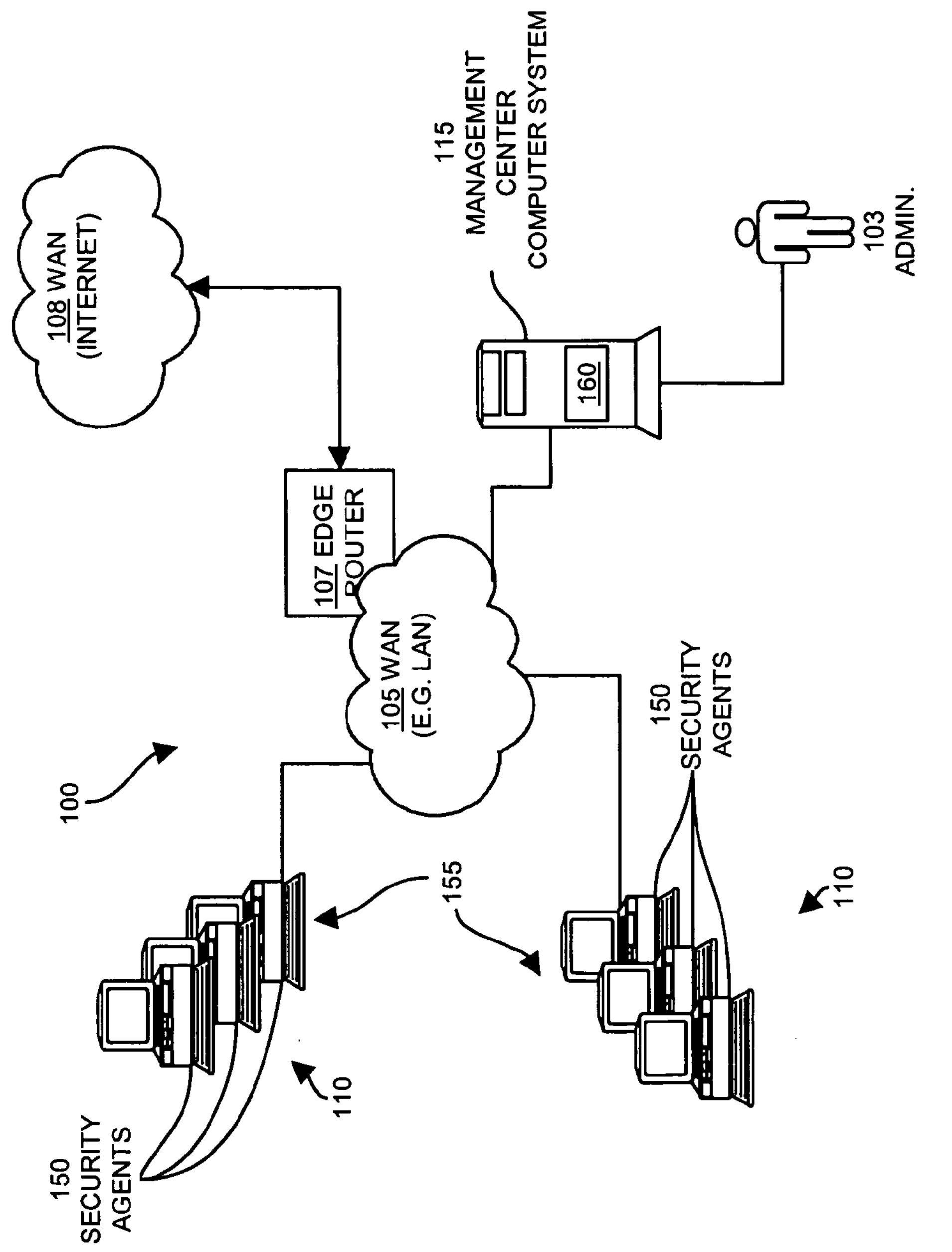

100
108 WAN (INTERNET)
107 EDGE ROUTER
105 WAN (E.G. LAN)
115 MANAGEMENT CENTER COMPUTER SYSTEM
160
103 ADMIN.
150 SECURITY AGENTS
155
110
150 SECURITY AGENTS
155
110

FIG. 1

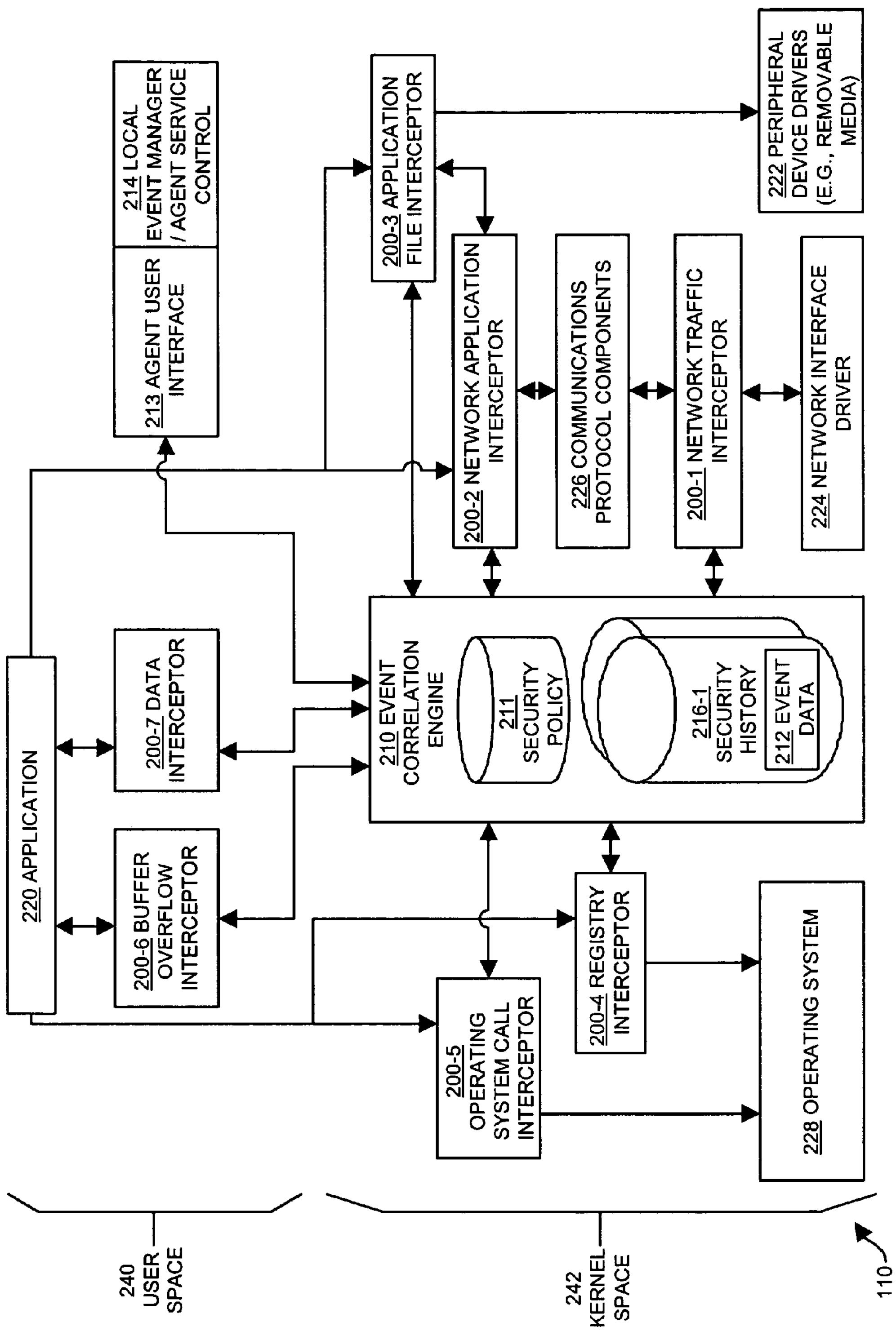

214 LOCAL EVENT MANAGER / AGENT SERVICE CONTROL
213 AGENT USER INTERFACE
200-3 APPLICATION FILE INTERCEPTOR
222 PERIPHERAL DEVICE DRIVERS (E.G., REMOVABLE MEDIA)
200-2 NETWORK APPLICATION INTERCEPTOR
226 COMMUNICATIONS PROTOCOL COMPONENTS
200-1 NETWORK TRAFFIC INTERCEPTOR
224 NETWORK INTERFACE DRIVER
220 APPLICATION
200-7 DATA INTERCEPTOR
200-6 BUFFER OVERFLOW INTERCEPTOR
210 EVENT CORRELATION ENGINE
211 SECURITY POLICY
216-1 SECURITY HISTORY
212 EVENT DATA
200-4 REGISTRY INTERCEPTOR
200-5 OPERATING SYSTEM CALL INTERCEPTOR
228 OPERATING SYSTEM
240 USER SPACE
242 KERNEL SPACE
110

FIG. 2

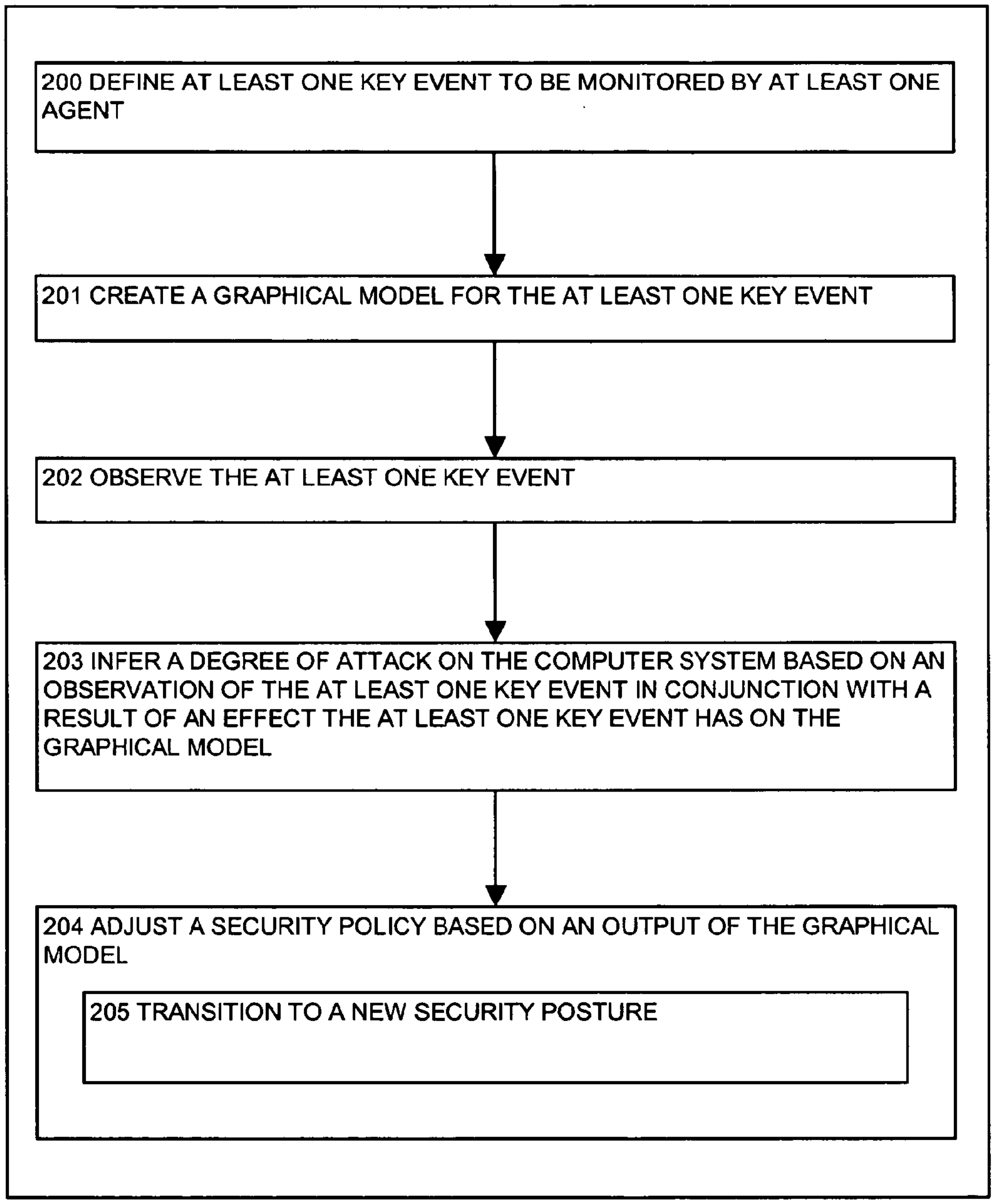

200 DEFINE AT LEAST ONE KEY EVENT TO BE MONITORED BY AT LEAST ONE AGENT
201 CREATE A GRAPHICAL MODEL FOR THE AT LEAST ONE KEY EVENT
202 OBSERVE THE AT LEAST ONE KEY EVENT
203 INFER A DEGREE OF ATTACK ON THE COMPUTER SYSTEM BASED ON AN OBSERVATION OF THE AT LEAST ONE KEY EVENT IN CONJUNCTION WITH A RESULT OF AN EFFECT THE AT LEAST ONE KEY EVENT HAS ON THE GRAPHICAL MODEL
204 ADJUST A SECURITY POLICY BASED ON AN OUTPUT OF THE GRAPHICAL MODEL
205 TRANSITION TO A NEW SECURITY POSTURE

FIG. 3

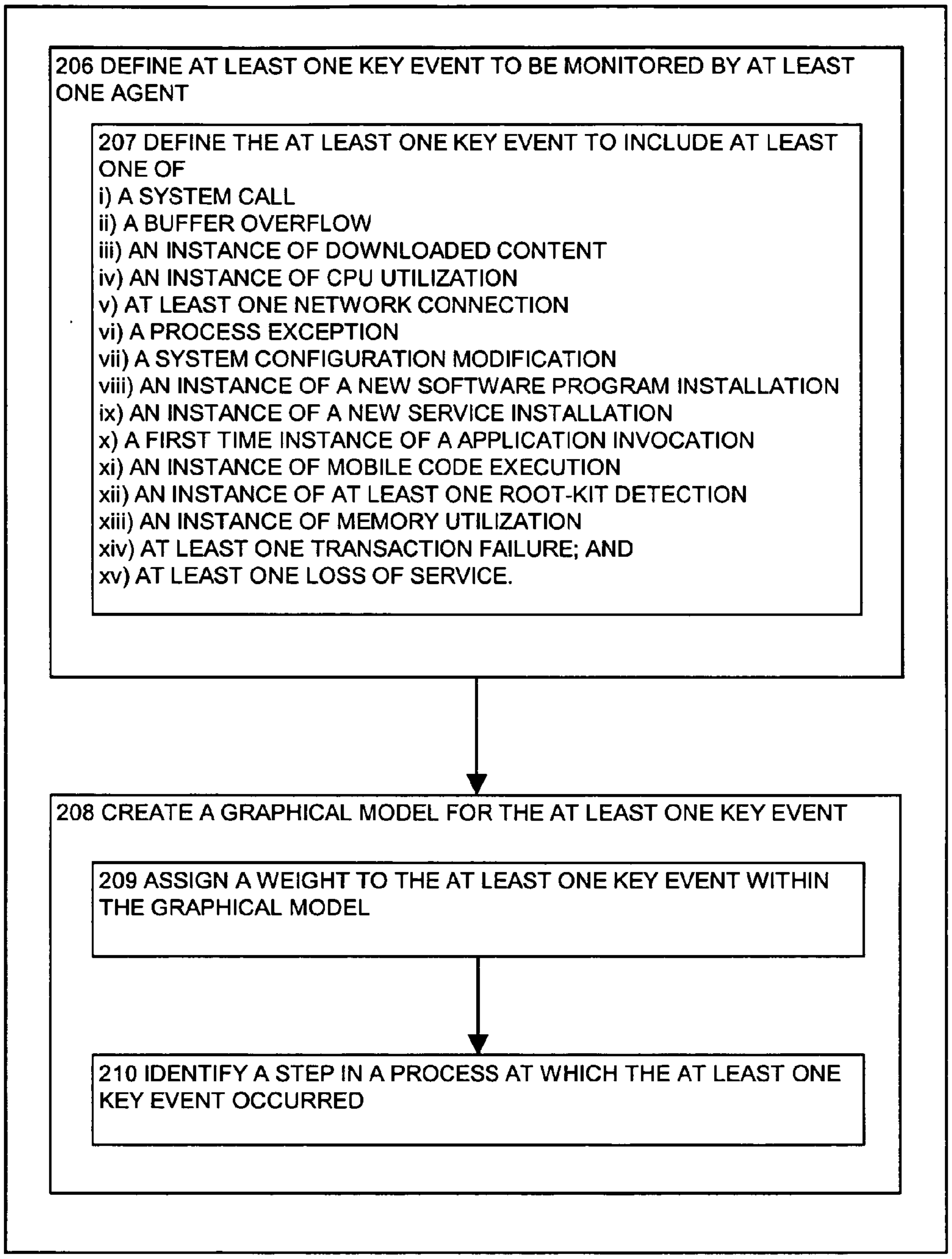

206 DEFINE AT LEAST ONE KEY EVENT TO BE MONITORED BY AT LEAST ONE AGENT
207 DEFINE THE AT LEAST ONE KEY EVENT TO INCLUDE AT LEAST ONE OF
i) A SYSTEM CALL
ii) A BUFFER OVERFLOW
iii) AN INSTANCE OF DOWNLOADED CONTENT
iv) AN INSTANCE OF CPU UTILIZATION
v) AT LEAST ONE NETWORK CONNECTION
vi) A PROCESS EXCEPTION
vii) A SYSTEM CONFIGURATION MODIFICATION
viii) AN INSTANCE OF A NEW SOFTWARE PROGRAM INSTALLATION
ix) AN INSTANCE OF A NEW SERVICE INSTALLATION
x) A FIRST TIME INSTANCE OF A APPLICATION INVOCATION
xi) AN INSTANCE OF MOBILE CODE EXECUTION
xii) AN INSTANCE OF AT LEAST ONE ROOT-KIT DETECTION
xiii) AN INSTANCE OF MEMORY UTILIZATION
xiv) AT LEAST ONE TRANSACTION FAILURE; AND
xv) AT LEAST ONE LOSS OF SERVICE.
208 CREATE A GRAPHICAL MODEL FOR THE AT LEAST ONE KEY EVENT
209 ASSIGN A WEIGHT TO THE AT LEAST ONE KEY EVENT WITHIN THE GRAPHICAL MODEL
210 IDENTIFY A STEP IN A PROCESS AT WHICH THE AT LEAST ONE KEY EVENT OCCURRED

FIG. 4

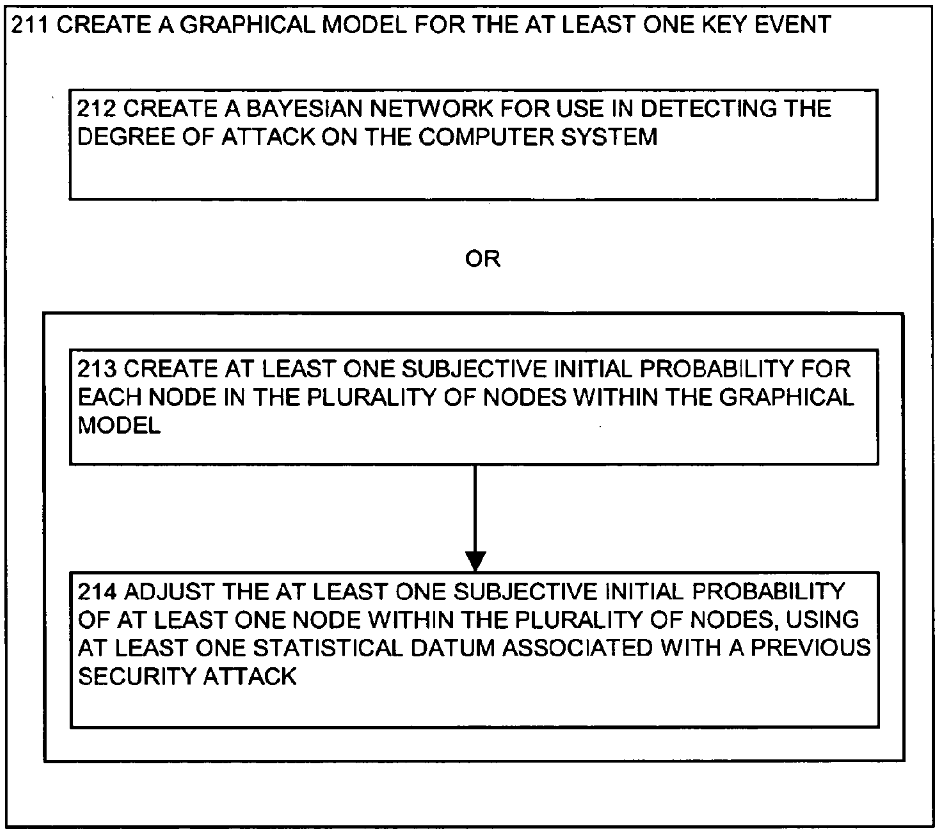

211 CREATE A GRAPHICAL MODEL FOR THE AT LEAST ONE KEY EVENT
212 CREATE A BAYESIAN NETWORK FOR USE IN DETECTING THE DEGREE OF ATTACK ON THE COMPUTER SYSTEM
OR
213 CREATE AT LEAST ONE SUBJECTIVE INITIAL PROBABILITY FOR EACH NODE IN THE PLURALITY OF NODES WITHIN THE GRAPHICAL MODEL
214 ADJUST THE AT LEAST ONE SUBJECTIVE INITIAL PROBABILITY OF AT LEAST ONE NODE WITHIN THE PLURALITY OF NODES, USING AT LEAST ONE STATISTICAL DATUM ASSOCIATED WITH A PREVIOUS SECURITY ATTACK

FIG. 5

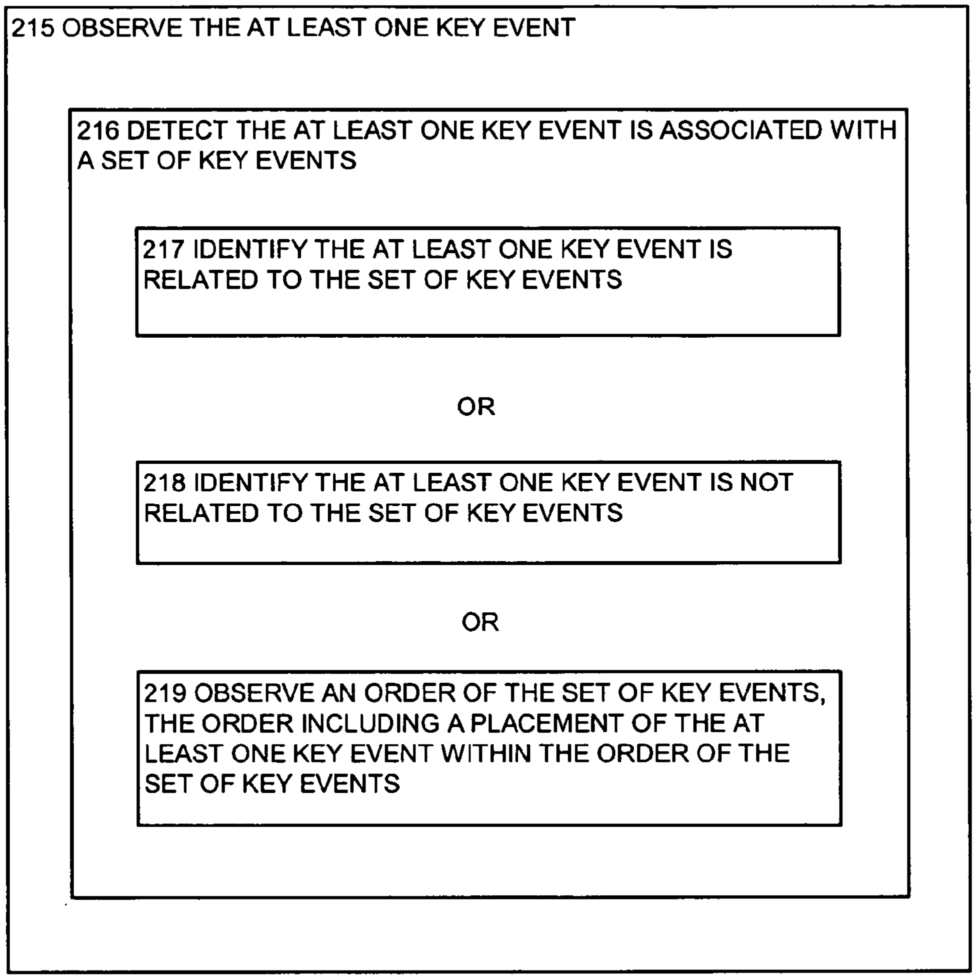

215 OBSERVE THE AT LEAST ONE KEY EVENT
216 DETECT THE AT LEAST ONE KEY EVENT IS ASSOCIATED WITH A SET OF KEY EVENTS
217 IDENTIFY THE AT LEAST ONE KEY EVENT IS RELATED TO THE SET OF KEY EVENTS
OR
218 IDENTIFY THE AT LEAST ONE KEY EVENT IS NOT RELATED TO THE SET OF KEY EVENTS
OR
219 OBSERVE AN ORDER OF THE SET OF KEY EVENTS, THE ORDER INCLUDING A PLACEMENT OF THE AT LEAST ONE KEY EVENT WITHIN THE ORDER OF THE SET OF KEY EVENTS

FIG. 6

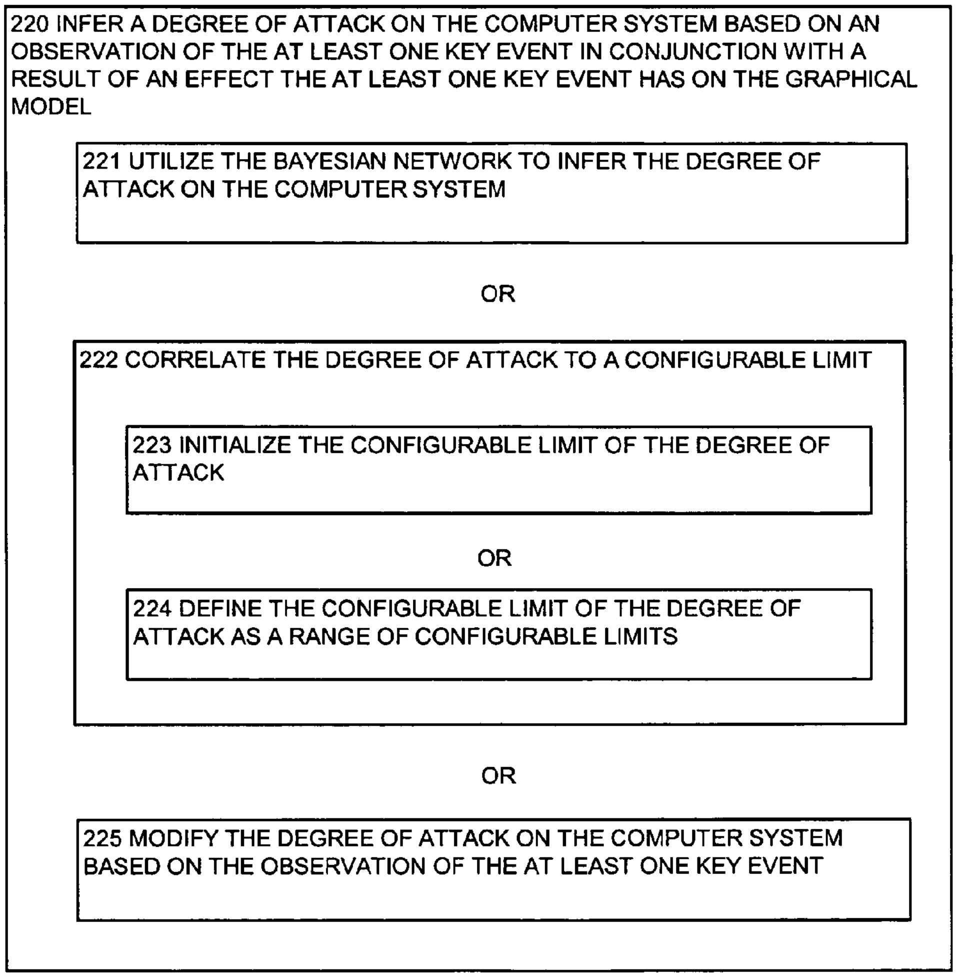

220 INFER A DEGREE OF ATTACK ON THE COMPUTER SYSTEM BASED ON AN OBSERVATION OF THE AT LEAST ONE KEY EVENT IN CONJUNCTION WITH A RESULT OF AN EFFECT THE AT LEAST ONE KEY EVENT HAS ON THE GRAPHICAL MODEL
221 UTILIZE THE BAYESIAN NETWORK TO INFER THE DEGREE OF ATTACK ON THE COMPUTER SYSTEM
OR
222 CORRELATE THE DEGREE OF ATTACK TO A CONFIGURABLE LIMIT
223 INITIALIZE THE CONFIGURABLE LIMIT OF THE DEGREE OF ATTACK
OR
224 DEFINE THE CONFIGURABLE LIMIT OF THE DEGREE OF ATTACK AS A RANGE OF CONFIGURABLE LIMITS
OR
225 MODIFY THE DEGREE OF ATTACK ON THE COMPUTER SYSTEM BASED ON THE OBSERVATION OF THE AT LEAST ONE KEY EVENT

FIG. 7

METHODS AND APPARATUS PROVIDING COMPUTER AND NETWORK SECURITY UTILIZING PROBABILISTIC POLICY REPOSTURING

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the benefit of U.S. Provisional Patent Application No. 60/751,439, filed on Dec. 16, 2005, which is incorporated herein by reference.

BACKGROUND

[0002] Computer systems, networks and data centers are exposed to a constant and differing variety of attacks that expose vulnerabilities of such systems in order to compromise their security and/or operation. As an example, various forms of malicious software program attacks include viruses, worms, Trojan horses and the like that computer systems can obtain over a network such as the Internet. Quite often, users of such computer systems are not even aware that such malicious programs have been obtained within the computer system. Once resident within a computer, a malicious program that executes might disrupt operation of the computer to a point of inoperability and/or might spread itself to other computers within a network or data center by exploiting vulnerabilities of the computer's operating system or resident application programs. Other malicious programs might operate within a computer to secretly extract and transmit information within the computer to remote computer systems for various suspect purposes. As an example, spyware is a form of software that can execute in the background (e.g., unbeknownst to users) of a computer system and can perform undesirable processing operations such as tracking, recording and transmitting user input from the spyware-resident computer system to a remote computer system. Spyware can allow remote computes to silently obtain otherwise confidential information such as usernames and passwords required to access protected data, lists, contents of files or even remote web sites user account information.

[0003] Computer system developers, software developers and security experts have created many types of conventional preventive measures that operate within conventional computer systems in an attempt to prevent operation of malicious programs from stealing information or from compromising proper operation of the computer systems. As an example, conventional virus detection software operates to periodically download a set of virus definitions from a remotely located server. Once the virus detection software obtains the definitions, the security software can monitor incoming data received by the computer system, such as email messages containing attachments, to identify viruses defined within the virus definitions that might be present within the data accessed by the computer. Such data might be obtained over a network or might be unknowingly resident on a computer readable medium, such as a disk or CD-ROM that a user inserts into the computer. Upon detection of inbound data containing a virus or other malicious program, the virus detection software can quarantine the inbound data so that a user of the computer system will not execute code or access the data containing the detected virus that might result in compromising the computer's operation.

[0004] Other examples of conventional malicious attacks, intrusions, or undesirable processing that can cause problems within computer systems or even entire computer networks include virus attacks, worm attacks, trojan horse attacks, denial-of-service attacks, a buffer overflow operations, execution of malformed application data, and execution of malicious mobile code. Virus attacks, worm attacks, and trojan horse attacks are variants of each other that generally involve the execution of a program, for which a user often is unaware of its existence, that performs some undesired processing operations to comprise a computer's proper operation. A denial-of-service attack operates to provide an intentional simultaneous barrage of packets (e.g., many connection attempts) emanating from many different computer systems to one or more target computer systems, such as a web site, in order to intentionally cause an overload in processing capabilities of the target computer resulting in disruption of service or a business function provided by the target computer. Denial of Service attacks may also seek to crash the targeted machine (rather than simply consume resources). Buffer overflow attacks occur when programs do not provide appropriate checks of data stored in internal data structures within the software that result in overwriting surrounding areas of memory. Attacks based on buffer overflows might allow an attacker to execute arbitrary code on the target system to invoke privileged access, destroy data, or perform other undesirable functions. Malformed application data attacks might result in an application containing a code section that, if executed, provides access to resources that would otherwise be private to the application. Such attacks can expose vulnerabilities due to an incorrect implementation of the application, for example by failing to provide appropriate data validity checks, or allowing data stream parsing errors, and the like.

[0005] Many of the conventional malicious programs and mechanisms for attack of computer systems, such as viruses and worms, include the ability to redistribute themselves to other computer systems or devices within a computer network, such that several computers become infected and experience the malicious processing activities discussed above. Some conventional attempts to prevent redistribution of malicious programs include implementing malicious program detection mechanisms such as virus detection software within firewalls or gateways between different portions of networked computer systems in order to halt propagation of malicious programs to sub-networks.

SUMMARY

[0006] Conventional technologies for providing computer security suffer from a variety of deficiencies. In particular, conventional technologies for providing computer security are limited in that conventional security software programs rely on the ability to periodically remotely receive information such as virus definitions that allow the conventional security software programs to identify and quarantine malicious programs. Many of the most common conventional forms of security software such as virus definitions programs rely upon obtaining the periodic virus definition updates from a centralized server accessed over the Internet that is maintained by the vendor of the security software. As a result, the most recent virus definition updates only reflects those viruses that have been recently detected, fingerprinted in inserted into the virus definition file by the vendor of that maintains and distributes the virus definition files.

[0007] Because conventional security software programs require periodic updates, such conventional security software programs are only as good as the most recent updates of the malicious program definitions (e.g., virus definitions) that individual instances of the conventional protection software have been able to receive. As an example, conventional virus detection software will not recognize viruses created and transmitted to a computer system that have not yet been identified and/or defined within the most recent update of a set of virus definitions obtained from a remote server. Accordingly, the malicious program code or data not defined within the most recent virus definitions update may be successfully inserted and executed within computer systems in a network in order to perform some of the malicious processing discussed above, even though such systems are equipped with conventional security software (i.e., virus detection software).

[0008] As a result, conventional security software program implementations are often several steps behind the prevention and spread of new attacks that are constantly being created and disseminated by malicious program developers. This problem is compounded by the fact that modern malicious programs are able to distribute themselves quickly to hundreds or thousands of computer systems on a network such as the Internet within a short amount of time, such as several hours, whereas most conventional security software only obtains updates on a less frequent basis, such as nightly.

[0009] Embodiments disclosed herein significantly overcome such deficiencies and provide a system that includes a probabilistic security policy re-posturing process. The probabilistic security policy re-posturing process rapidly identifies malicious attacks and prevents the spread of such attacks to other computer systems. In effect, embodiments disclosed herein provide for a self-healing computer network system. Embodiments disclosed herein include one or more security agents that operate within individual host computer systems in a network. The security agents can interact with a management center to obtain a security policy that contains a set of rules that indicate types of operations that may be allowed or disallowed within computer system. Once a security agent has obtained the security policy, the security agent operates a plurality of security interceptors that can watch over and monitor processing operations performed by various software and hardware components within the host computer system that that security agent protects. The security agent provides security to a computerized device by detecting processing outcomes produced via operation of a sequence of related processing operations within the computerized device. As an example, processing operations related to an inbound connection to a Web server can be monitored by various interceptors operating within different parts of the computer system's operating system and application layer code in order to detect the related sequence of processing operations that the inbound Web server connection attempt triggers. Each interceptor detects a specific event and transfers that event to an event correlation engine that records the processing outcomes and the sequence of related processing operations in a security history. The event correlation engine identifies a security violation when one of the detected processing operations in the security history produces a processing outcome that violates a security policy. This may be before, during or after occurrence of an undesired processing outcome within computer system such as a system crash, system error, protection violation, process disruption or other such undesired action as defined within the security policy. The security agent is then able to subsequently detect attempted performance of a similar sequence of related processing operations that attempt to produce at least one processing outcome that violates the security policy. In response, the security agent denies operation of at least a portion of the sequence of related processing operations within the computerized device to avoid violation of the security policy. The security agents can also mark or otherwise identify sequences of processing operations that led up to the security violation as a disallowed sequence of processing operations and can disseminate this information to other security agents operating on other host computer systems in the network in real-time (e.g., upon detection) in order to spread the knowledge of the behavior or processing pattern that the malicious attack attempted to perform on the computer system the detected the attack, so that other computer systems will not be vulnerable to the attack.

[0010] Embodiments disclosed herein include a computer system executing a probabilistic security policy re-posturing process. The probabilistic security policy re-posturing process defines a set of key events to be monitored by at least one agent. The probabilistic security policy re-posturing process creates a graphical model, such as a Bayesian Network, for the set of key events. The probabilistic security policy re-posturing process observes the set of key events. In one embodiment, the set of key events are related to each other. In another embodiment, the set of key events are not related to each other. In yet another embodiment, the set of key events have a causal relationship with each other. The key events are observed, and inputted into the Bayesian Network. Using the resulting data, the probabilistic security policy re-posturing process infers a degree of security attack on the computer system, and adjusts the security policy accordingly.

[0011] Embodiments disclosed herein include a computer system executing a probabilistic security policy re-posturing process. The probabilistic security policy re-posturing process defines at least one key event to be monitored by at least one agent, and creates a creating a graphical model for the at least one key event. The probabilistic security policy re-posturing process observes the at least one key event, and infers a degree of attack on the computer system based on an observation of the at least one key event in conjunction with a result of an effect the at least one key event has on the graphical model. The probabilistic security policy re-posturing process then adjusts a security policy based on an output of the graphical model.

[0012] During an example operation of one embodiment, suppose the probabilistic security policy re-posturing process is monitoring a computer system. The probabilistic security policy re-posturing process defines a set of key events, including, for example, a buffer overflow, and creates a graphical model, such as a Bayesian Network, that infers a degree of probability of an attack on the computer system, based on the occurrence of a buffer overflow. The probabilistic security policy re-posturing process observes the activity on the computer system, and detects an occurrence of a buffer overflow. The probabilistic security policy re-posturing process infers a degree of attack on the computer system, for example, fifty percent, based on the buffer overflow, and the result of inputting the instance of the buffer overflow into the Bayesian Network. Based on the probability that there is an attack on the computer system, the probabilistic security policy re-posturing process adjusts the security policy on the computer system. In one embodiment, the security policies of other computer systems also protected by the probabilistic security policy re-posturing process are also adjusted.

[0013] Other embodiments disclosed herein include any type of computerized device, workstation, handheld or laptop computer, or the like configured with software and/or circuitry (e.g., a processor) to process any or all of the method operations disclosed herein. In other words, a computerized device such as a computer or a data communications device or any type of processor that is programmed or configured to operate as explained herein is considered an embodiment disclosed herein.

[0014] Other embodiments that are disclosed herein include software programs to perform the steps and operations summarized above and disclosed in detail below. One such embodiment comprises a computer program product that has a computer-readable medium including computer program logic encoded thereon that, when performed in a computerized device having a coupling of a memory and a processor, programs the processor to perform the operations disclosed herein. Such arrangements are typically provided as software, code and/or other data (e.g., data structures) arranged or encoded on a computer readable medium such as an optical medium (e.g., CD-ROM), floppy or hard disk or other a medium such as firmware or microcode in one or more ROM or RAM or PROM chips or as an Application Specific Integrated Circuit (ASIC). The software or firmware or other such configurations can be installed onto a computerized device to cause the computerized device to perform the techniques explained herein as embodiments disclosed herein.

[0015] It is to be understood that the system disclosed herein may be embodied strictly as a software program, as software and hardware, or as hardware alone. The features, as explained herein, may be employed in data communications devices and other computerized devices and software systems for such devices such as those manufactured by Cisco Systems, Inc. of San Jose, Calif.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The foregoing and other objects, features and advantages disclosed herein will be apparent from the following description of particular embodiments disclosed herein, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles disclosed herein.

[0017] FIG. **1** illustrates an example configuration of a network environment that includes a security system configured as disclosed herein.

[0018] FIG. **2** illustrates example architecture of the computerized device configured with a security system in one example configuration.

[0019] FIG. **3** illustrates a flowchart of a procedure performed by the system of FIG. **1** when the probabilistic security policy re-posturing process defines at least one key event to be monitored by at least one agent, according to one embodiment disclosed herein.

[0020] FIG. **4** illustrates a flowchart of a procedure performed by the system of FIG. **1** when the probabilistic security policy re-posturing process defines at least one key event to be monitored by at least one agent, and creates a graphical model for the at least one key event, according to one embodiment disclosed herein.

[0021] FIG. **5** illustrates a flowchart of a procedure performed by the system of FIG. **1** when the probabilistic security policy re-posturing process creates a graphical model for the at least one key event, such as a Bayesian network, for use in detecting the degree of attack on the computer system, according to one embodiment disclosed herein.

[0022] FIG. **6** illustrates a flowchart of a procedure performed by the system of FIG. **1** when the probabilistic security policy re-posturing process observes the at least one key event, according to one embodiment disclosed herein.

[0023] FIG. **7** illustrates a flowchart of a procedure performed by the system of FIG. **1** when the probabilistic security policy re-posturing process infers a degree of attack on the computer system based on an observation of the at least one key event in conjunction with a result of an effect the at least one key event has on the graphical model, according to one embodiment disclosed herein.

DETAILED DESCRIPTION

[0024] Embodiments disclosed herein include a computer system executing a probabilistic security policy re-posturing process. The probabilistic security policy re-posturing process defines a set of key events to be monitored by at least one agent. The probabilistic security policy re-posturing process creates a graphical model, such as a Bayesian Network for the set of key events. The probabilistic security policy re-posturing process observes the set of key events. In one embodiment, the set of key events are related to each other. In another embodiment, the set of key events are not related to each other. In yet another embodiment, the set of key events have a causal relationship with each other. The key events are observed, and inputted into the graphical model. Using the resulting data, the probabilistic security policy re-posturing process infers a degree of security attack on the computer system, and adjusts the security policy accordingly.

[0025] Embodiments disclosed herein include a computer system executing a probabilistic security policy re-posturing process. The probabilistic security policy re-posturing process defines at least one key event to be monitored by at least one agent, and creates a creating a graphical model for the at least one key event. The probabilistic security policy re-posturing process observes the at least one key event, and infers a degree of attack on the computer system based on an observation of the at least one key event in conjunction with a result of an effect the at least one key event has on the graphical model. The probabilistic security policy re-posturing process then adjusts a security policy based on an output of the graphical model.

[0026] FIG. **1** illustrates an example computer networking environment **100** suitable for use in explaining example embodiments disclosed herein. The computer networking environment **100** includes a computer network **105** such as a local area network (LAN) that interconnects a security management computer system **115**, an edge router **107** and a plurality of host computer systems **110**, each of which operates (e.g., executes, runs, interprets or otherwise performs) a agent **150** configured as disclosed herein. Each agent **150** is running an instance of the probabilistic security policy re-posturing process **155**. The security management computer system **115** also operates a management center application **160** that operates as disclosed herein. The edge router **107** couples the network **105** to a wide area network (WAN) **108** such as the Internet that allows communication between the computer systems **110**, **115** and other computers worldwide.

Note that the management center computer **115** may be isolated form the WAN **108** by a firewall that is not shown in this example.

[0027] The host computers **110** may be any type of computer system, workstation, server (e.g., web server), personal computer, laptop, mainframe, personal digital assistant device, general purpose or dedicated computing device or the like that operate any type of software, firmware or operating system. They may be physically or wirelessly coupled to the network **105** to support communications. The security agents **150** and management center application **160** operate to dynamically detect and prevent malicious attacks on the computers **110** without requiring the security agents **150** to continuously and periodically download signature or virus definition files. Generally, an administrator **103** installs the security agents **150** (including the probabilistic security policy re-posturing process **155**) on the computer systems **110** that are to be protected and they are responsible for enforcing the appropriate security policy on those systems.

[0028] The security agents **150** (including the probabilistic security policy re-posturing process **155**) have the ability to learn what causes security violations such as malicious attacks by monitoring, analyzing and recording processing behavior and events of the computer system **110** that occur prior to the security violation taking place, in order to prevent such events from occurring in the future. In other words, the security system disclosed herein in able to monitor and record processing behavior that results in an undesired processing operation such as a process exception, system crash or the like and is able to analyze recorded processing operations that led up to undesired operation or problem to identify the root cause of the failure. Once identified, the security system is able to prevent that single operation or sequence of processing operations identified as the root cause of failure from executing again on that or other computer system in order to avoid further security violations and to prevent such attacks on other computers. A security agent as disclosed herein can thus learn of new types of malicious attacks without having seen processing that causes such attacks in the past, and can prevent that attack in the future. The ability to learn of processing associated with a new attack, identify its root cause, and prevent it from happening in the future can occur without external input (e.g., virus definition files) being received by a computer system equipped with the security agent.

[0029] Security agent operation as explained herein includes being preprogrammed with certain known security violations in a rule-based security policy and preventing them from happening even a first time. In addition, such processing also involves recording and post-processing security history event data that result in a security violation (i.e., that was not preprogrammed and thus unrecognizable a first time) to identify a root cause (e.g., one or more processing operations or events) of the security violation within the computer system in order to prevent it from happening a second time. This can involve performing a local comparison of several security histories collected by a agent **150** in a single computer system **110** to identify a common pattern of processing activity that results in an undesirable processing outcome (i.e., a security violation). The security agents **150** can also transmit event and security history information to the management center **115**.

[0030] The management center **115** acts as a central repository for all event log records generated by the security agents **150** and provides functions for monitoring and reporting. The management center **115** also correlates event records generated from security agents **150** operating on different computer systems **110** for purposes of detecting suspicious activity in the network.

[0031] FIG. **2** illustrates an architecture of a host computer system **110** configured with a security agent in accordance with one example embodiment. The security agent components include a plurality of security interceptors **200-1** through **200-7** including, for example, a network traffic interceptor **200-1**, the network application interceptor **200-2**, a file interceptor **200-3**, a registry interceptor **200-4**, a system call interceptor **200-5**, a buffer overflow interceptor **200-6** and a data interceptor **200-7**. The agent **150** in this example configuration also includes an event correlation engine **210**, a security agent user interface **213**, and local event manager **214**. The event correlation engine **210** stores a security policy **211** that contains rules that are used to instruct the agent **150** to protects the computer **110** on which it operates by interpreting and enforcing the rules to restrict the operations that may be performed by that computer **110**. An administrator **103** uses the management center application **160** to create and distribute security policies to each computer system **110** to be protected.

[0032] In one configuration, the network traffic interceptor **200-1** resides between a communications protocol component **226** (such as a TCP driver), and the network interface card **224** or other communications interface. The network traffic interceptor **200-1** looks at packets coming from the network before they get to the native operating system TCP stack and can detect malicious operations or instructions such as a remote computer scanning the computer system **110**. Such attacks can include, for example, a ping of death attack, a TCP SYN flood attack, port scanning attacks and so froth. Other security interceptors **200** can include packet interceptors, connection interceptors, file sharing interceptors, data filter interceptors, registry interceptors, system call interceptors, and the like. The interceptors **200** can be installed and executed by using, for example, windows registry keys that create dependencies on standard Operating Systems (OS) dynamically linked libraries (dlls) so that the interceptor dlls **200** are loaded along with the appropriate windows dlls that they monitor. The interceptors can thus serve as wrappers to monitor processing operations of all calls made to any specific computer components.

[0033] This example configuration also includes several components that operate within the computer system **110** that are not part of the security agent architecture itself. In particular, this example configuration includes one or more software applications **220** that execute within a user space **240** within the computer system **110**. The computer system **110** further operates several components in kernel space **242** such as one or more device peripheral device drivers **222**, a network interface driver **224**, communications protocol components **226**, and an operating system **228**. It is to be understood that the components **222** through **228** are illustrated as separate for purposes of description of operations disclosed herein, and that they may be combined together, such as an operating system that includes device drivers **222** and communication protocol components **226**.

[0034] Generally, according to operations of embodiments disclosed herein, the interceptors **200** monitor processing activities and collect and report event data **212** to the event correlation engine **210** for the respective standard processing components **220** through **228** within the user and kernel spaces **240** and **242**. The event correlation engine **210** stores the event data within one or more security histories **216**. Event data **212** can include things such as the identification of new connection requests made to the network interface driver **224**, as detected by the network traffic interceptor **200-1**. As another example, the application file interceptor **200-2** can identify a processing activity such as an application **220** accessing a particular file via an operating system call and report this as event data **212** to the event correlation engine **210**. There may be other interceptors **200** besides those illustrated in FIG. **2** and thus the interceptors **201** through **206** are shown by way of example only. The event correlation engine **210** correlates the event data **212** against the security policy **211** in order to provide an indication to the interceptors **200** of whether or not the processing activity associated with the event data should be allowed. The event correlation engine **210** can also instruct the interceptors **200** to collect more or less event data **212** as needed. By being able to track operations, in the event of an undesirable processing operation, the behavior of the computer system **110** can be analyzed and the series of events that took place that lead up the undesirable processing operation can be "fingerprinted" and marked so that if they occur again, they can be prevented prior to their full execution. In addition, by recording traces from multiple failures and determining a commonality between them, if several computer systems suffer similar attacks, a commonality between the attacks can be identified and prevented in the future, even in situations where the attacking program morphs its identity or changes it content.

[0035] Further details of configurations explained herein will now be provided with respect to a flow chart of processing steps that show the high level operations disclosed herein.

[0036] FIG. **3** is a flowchart of the steps performed by the probabilistic security policy re-posturing process **155** when it defines at least one key event to be monitored by at least one agent **150**.

[0037] In step **200**, the probabilistic security policy re-posturing process **155** defines at least one key event to be monitored by at least one agent **150**. In an example configuration, the probabilistic security policy re-posturing process **155** defines a set of key events to be monitored by an agent **150**. The set of key events are defined, for example, with help of group of top security experts/analysts. The probabilistic security policy re-posturing process **155** hooks key processing points for both the computer system, and applications executing on the computer system. The processing points are defined as potential security enforcement points, for example, invoking another application, modifying the system configuration, etc. The processing points can also include detection points, for example, process exception handling, Buffer Overflow detection, etc. In an example embodiment, a subset of these observation points are used to probabilistically determine if an attack on a computer system is in progress or mal-ware is executing locally on the computer system.

[0038] In step **201**, the probabilistic security policy re-posturing process **155** creates a graphical model for the at least one key event. In an example configuration, for every key event defined, the probabilistic security policy re-posturing process **155** creates a graphical model, such as a directed graphical model, that identifies casual relations between the monitored events. When network is created, initial subjective probabilities are defined using expert opinions, and available supporting statistical data of past attacks on computer systems. In an example configuration, the probability of an attack on the computer system increases (or possibly decreases) based upon observation of the key events. In an example embodiment, the graphical model represents a set of events wherein distinct subsets are assigned a probability.

[0039] In step **202**, the probabilistic security policy re-posturing process **155** observes the at least one key event. In an example configuration, the agent **150**, executing the probabilistic security policy re-posturing process **155**, monitors events on the computer system. As events occur, the probabilistic security policy re-posturing process **155** identifies key events that could be an indication of a security attack on the computer system. In an example configuration, the probabilistic security policy re-posturing process **155** observes a key event, such as an instance of a software application being installed on the computer system.

[0040] In step **203**, the probabilistic security policy re-posturing process **155** infers a degree of attack on the computer system, based on an observation of the at least one key event, in conjunction with a result of an effect the at least one key event has on the graphical model. In an example configuration, the probabilistic security policy re-posturing process **155** observes a set of key events occurring on the computer system. The key events observed by the probabilistic security policy re-posturing process **155**, can be compiled in sequence, or compiled as a set of key events, yielding different probabilities of an attempted attack on the computer system. For example, the probabilistic security policy re-posturing process **155** detects a process exception. The probabilistic security policy re-posturing process **155** may have assigned the process exception a probability of, for example, five percent, within the graphical model. In this example, a process exception could merely be the result of a poorly written application. In this same example, the probabilistic security policy re-posturing process **155** detects code executing from a buffer. Code executing from a buffer may indicate a buffer overflow attack, but it could also easily be licensing code being executed. Thus, the probabilistic security policy re-posturing process **155** assigns code executing from a buffer a low probability of being an exploit, for example, twenty five percent. However, when the probabilistic security policy re-posturing process **155** observes both the process exception and a buffer overflow, the graphical model tabulates these two occurrences as suspicious, and assigns the probability of an attack on the computer system to a higher percentage, for example ninety percent. In an example embodiment, the probabilistic security policy re-posturing process **155** identifies a threshold associated with an attack on the computer system. Once the result of the observed key events, in conjunction with the output of the graphical model surpasses a specified threshold, the probabilistic security policy re-posturing process **155** indicates that an attack on the computer system is likely.

[0041] In step **204**, the probabilistic security policy re-posturing process **155** adjusts a security policy based on an output of the graphical model. In an example configuration, the probabilistic security policy re-posturing process **155** identifies a degree of attack on the compute system based on observed key events in conjunction with the graphical model. In response, the probabilistic security policy re-posturing process **155** modifies the security policy. As the threat of attack increases, tighter security policies can be employed. Likewise, as the threat of attack decreases, the security policies can be relaxed.

[0042] In step **205**, the probabilistic security policy re-posturing process **155** transitions to a new security posture. In an example configuration, the probabilistic security policy re-posturing process **155** defines security postures. An example of a security posture may be, "when an attack on the computer system is detected, and the result of the graphical model indicates the probability of an attack exceeds seventy percent, deny all new network connections". Thus, when the probabilistic security policy re-posturing process **155** identifies an attack on the computer system, the probabilistic security policy re-posturing process **155** transitions to a new security posture. That new security posture may tighten or relax the level of security on the computer system.

[0043] FIG. **4** is a flowchart of the steps performed by the probabilistic security policy re-posturing process **155**, when it defines at least one key event to be monitored by at least one agent **150**, and creates a graphical model for the at least one key event.

[0044] In step **206**, the probabilistic security policy re-posturing process **155** defines at least one key event to be monitored by at least one agent **150**. In an example configuration, the probabilistic security policy re-posturing process **155** defines a set of key events to be monitored by an agent **150**. The probabilistic security policy re-posturing process **155** hooks key processing points for both the computer system and applications executing on the computer system. In another example configuration, more than one agent **150** can monitor the set of key events. Examples of key events are detailed in sub step **207**.

[0045] In step **207**, the probabilistic security policy re-posturing process **155** defines the at least one key event to include at least one of:

[0046] i) a system call

[0047] ii) a buffer overflow

[0048] iii) an instance of downloaded content

[0049] iv) an instance of CPU utilization

[0050] v) at least one network connection

[0051] vi) a process exception

[0052] vii) a system configuration modification

[0053] viii) an instance of a new software program installation

[0054] ix) an instance of a new service installation

[0055] x) a first time instance of a application invocation

[0056] xi) an instance of mobile code execution

[0057] xii) an instance of at least one root-kit detection

[0058] xiii) an instance of memory utilization

[0059] xiv) at least one transaction failure and

[0060] xv) at least one loss of service.

Other system events can be defined as key events.

[0061] In step **208**, the probabilistic security policy re-posturing process **155** creates a graphical model for the at least one key event. In an example embodiment, the probabilistic security policy re-posturing process **155** identifies a set of key events. The probabilistic security policy re-posturing process **155** then creates a graphical model for the set of key events. For example, the probabilistic security policy re-posturing process **155** creates a graphical model that infers an attack is occurring on the computer system if a process exception, a buffer overflow, and high CPU utilization occur at the same time on the computer system.

[0062] In step **209**, the probabilistic security policy re-posturing process **155** assigns a weight to the at least one key event within the graphical model. In an example embodiment, the probabilistic security policy re-posturing process **155** identifies a set of key events. The probabilistic security policy re-posturing process **155** then creates a graphical model for the set of key events, and assigns a weight to each of the key events within the graphical model. For example, the probabilistic security policy re-posturing process **155** may assign a weight of a five percent chance of an attack on the computer system if the probabilistic security policy re-posturing process **155** observes an instance of a new software application installation. The probabilistic security policy re-posturing process **155** may assign a weight of fifteen percent chance of an attack on the computer system if the probabilistic security policy re-posturing process **155** observes high CPU utilization. The probabilistic security policy re-posturing process **155** may assign a weight of a fifty percent chance of an attack on the computer system if the probabilistic security policy re-posturing process **155** observes an instance of a new software installation, and high CPU utilization on the computer system. However, the probabilistic security policy re-posturing process **155** may only assign a weight of a twenty five percent chance of an attack on the computer system if the probabilistic security policy re-posturing process **155** observes an instance of a new software installation, and a process exception on the computer system.

[0063] In step **210**, the probabilistic security policy re-posturing process **155** identifies a step in a process at which the at least one key event occurred. In an example embodiment, the probabilistic security policy re-posturing process **155** creates a graphical model for the set of key events, and assigns a weight to each key event, based on the step in the process at which the key event occurred. For example, a modification to a system configuration that occurs after a first time invocation of a software application is more likely to be a security attack on the computer system than a modification to a system configuration that occurs before a first time invocation of a software application. Thus, the probabilistic security policy re-posturing process **155** identifies the step in the process at which the key event occurs, and assigns a weight to that key event (within the graphical model), based on the step in the process at which the key event occurs.

[0064] FIG. **5** is a flowchart of the steps performed by the probabilistic security policy re-posturing process **155**, when it creates a graphical model for the at least one key event.

[0065] In step **211**, the probabilistic security policy re-posturing process **155** creates a graphical model for the at least one key event. In an example configuration, for every key event defined, the probabilistic security policy re-posturing process **155** creates a graphical model, such as a directed graphical model, that identifies casual relations between the monitored events.

[0066] In step **212**, the probabilistic security policy re-posturing process **155** creates a Bayesian network for use in detecting the degree of attack on the computer system. In an example configuration, the probabilistic security policy re-posturing process **155** creates a directed graphical model, such as a Bayesian Network to detect a degree of attack on the computer system. A Bayesian Network is a technique from the field of artificial intelligence that calculates probability based on a group of related or influential signs. The probabilistic security policy re-posturing process **155** identifies a set of key events, and assigns weights to key event for use with the Bayesian Network.

[0067] As the probabilistic security policy re-posturing process **155** observes the key events occurring on the computer system, the Bayesian Network is used to compute the degree of attack on the computer system.

[0068] Alternatively, in step **213**, the probabilistic security policy re-posturing process **155** creates at least one subjective initial probability for each node in a plurality of nodes within the graphical model. In an example embodiment, the probabilistic security policy re-posturing process **155** creates a graphical model for use in detecting attacks on the computer system. When network is created, the probabilistic security policy re-posturing process **155** defines initial subjective probabilities using expert opinions, and available supporting statistical data of past attacks on computer systems. The initial subjective probabilities are defined for each node on the graphical model defined by the probabilistic security policy re-posturing process **155**.

[0069] In step **214**, the probabilistic security policy re-posturing process **155** adjusts the at least one subjective initial probability of at least one node within the plurality of nodes, using at least one statistical datum associated with a previous security attack. The probability of an attack on the computer system increases (or possibly decreases) based upon observation of the key events. Thus, in an example configuration, the probabilistic security policy re-posturing process **155** adjusts the subjective initial probabilities using statistical data associated with previous security attacks on the computer system.

[0070] FIG. **6** is a flowchart of the steps performed by the probabilistic security policy re-posturing process **155**, when it observes the at least one key event.

[0071] In step **215**, the probabilistic security policy re-posturing process **155** observes the at least one key event. In an example configuration, the agent **150**, executing the probabilistic security policy re-posturing process **155**, monitors events on the computer system. As events occur, the probabilistic security policy re-posturing process **155** identifies key events that could be an indication of a security attack on the computer system. In an example configuration, the probabilistic security policy re-posturing process **155** observes a key event, such as an instance of a software application being installed on the computer system.

[0072] In step **216**, the probabilistic security policy re-posturing process **155** detects the at least one key event is associated with a set of key events. In an example configuration, the probabilistic security policy re-posturing process **155** detects a single key event. The probabilistic security policy re-posturing process **155** then determines the single key event is associated with a set of key events. The association of the single key event with the set of key events provides the probabilistic security policy re-posturing process **155** with additional information that may help in determining whether an attack is occurring on the computer system, and may also help the probabilistic security policy re-posturing process **155** determine the root cause of the attack (if any) on the computer system.

[0073] In step **217**, the probabilistic security policy re-posturing process **155** identifies the at least one key event is related to the set of key events. In an example configuration, the probabilistic security policy re-posturing process **155** detects a single key event, and then determines the single key event is associated with a set of key events. For example, the probabilistic security policy re-posturing process **155** detects an unfamiliar system call (i.e., the single key event), and a buffer overflow and process exceptions (i.e., a set of key events). The probabilistic security policy re-posturing process **155** determines that the unfamiliar system call (i.e., the single key event) is related to the buffer overflow and process exceptions (i.e., a set of key events) in that the buffer overflow and process exceptions (i.e., a set of key events) occurred after the unfamiliar system call (i.e., the single key event) occurred. Thus, the probabilistic security policy re-posturing process **155** determines a cause and effect between the unfamiliar system call (i.e., the single key event) and the buffer overflow and process exceptions (i.e., a set of key events). In one example embodiment, the set of key events is an ordered set of key events. In another example embodiment, the set of key events is an unordered set of key events.

[0074] Alternatively, in step **218**, the probabilistic security policy re-posturing process **155** identifies the at least one key event is not related to the set of key events. In an example configuration, the probabilistic security policy re-posturing process **155** detects a single key event, and then determines the single key event is not associated with a set of key events. For example, the probabilistic security policy re-posturing process **155** detects high CPU utilization (i.e., the single key event), and several network connections (i.e., a set of key events). The probabilistic security policy re-posturing process **155** determines that high CPU utilization (i.e., the single key event) is not related to the instance of several network connections (i.e., a set of key events). Thus, the probabilistic security policy re-posturing process **155** determines that while high CPU utilization (i.e., the single key event) and the instance of several network connections (i.e., a set of key events) may potentially be separate instances of an attack on the computer system, they are not related to the (potentially) same attack on the computer system.

[0075] Alternatively, in step **219**, the probabilistic security policy re-posturing process **155** observes an order of the set of key events, the order including a placement of the at least one key event within the order of the set of key events. In an example configuration, the probabilistic security policy re-posturing process **155** detects a set of key events occurring. The probabilistic security policy re-posturing process **155** observes the order in which the key events occurred to determine if the occurrence of those key events indicates an attack on the computer system. For example, an instance of a first time invocation of a software application, followed by high CPU utilization, followed by several strange system calls could indicate a higher probability of an attack on the computer system. However, an instance of high CPU utilization followed by a first time invocation of a software application would indicate that the instance of high CPU utilization is an indication of a lower probability of an attack on the computer system.

[0076] FIG. **7** is a flowchart of the steps performed by the probabilistic security policy re-posturing process **155**, when it infers a degree of attack on the computer system.

[0077] In step **220**, the probabilistic security policy re-posturing process **155** infers a degree of attack on the computer system based on an observation of the at least one key event in conjunction with a result of an effect the at least one key event has on the graphical model. In an example configuration, the probabilistic security policy re-posturing process **155** observes key events, and applies these key events to the graphical model. The key events are weighted within the graphical model, and the resulting effect of the key events determines the degree of attack on the computer system. It is the combination of the ability to hook and intercept key events on the computer system and the graphical model (including the learning abilities of the graphical model) that provides a very unique solution to determining the degree of attack on the computer system.

[0078] In step **221**, the probabilistic security policy re-posturing process **155** utilizes the Bayesian network to infer the degree of attack on the computer system. In an example embodiment, the probabilistic security policy re-posturing process **155** creates a Bayesian network for use in detecting the degree of attack on the computer system. The probabilistic security policy re-posturing process **155** creates a Bayesian Network to detect a degree of attack on the computer system, identifies a set of key events, and assigns weights to key event for use with the Bayesian Network. As the probabilistic security policy re-posturing process **155** observes the key events occurring on the computer system the Bayesian Network is used to infer the degree of attack on the computer system.

[0079] Alternatively, in step **222**, the probabilistic security policy re-posturing process **155** correlates the degree of attack to a configurable limit. In an example configuration, the probabilistic security policy re-posturing process **155** weights each key event within the graphical model to determine a degree of attack on the computer system. The probabilistic security policy re-posturing process **155** correlates the degree of attack to a configurable limit, such as a percentage of probability that an attack is occurring on the computer system.

[0080] In step **223**, the probabilistic security policy re-posturing process **155** initializes the configurable limit of the degree of attack. In an example embodiment, the probabilistic security policy re-posturing process **155** initializes the degree a probability of an attack on the computer system to zero. As the probabilistic security policy re-posturing process **155** observes key events, the degree a probability of an attack on the computer system is modified.

[0081] Alternatively, in step **224**, the probabilistic security policy re-posturing process **155** defines the configurable limit of the degree of attack as a range of configurable limits. In an example configuration, the probabilistic security policy re-posturing process **155** defines the configurable limit of attack on the computer system as a bounded limit. In another example configuration, the probabilistic security policy re-posturing process **155** defines the configurable limit as a range of configurable limits.

[0082] Alternatively, in step **225**, the probabilistic security policy re-posturing process **155** modifies the degree of attack on the computer system based on the observation of the at least one key event. In an example configuration, the probabilistic security policy re-posturing process **155** observes a set of key events. Based on the observation of the set of key events, the probabilistic security policy re-posturing process **155** modifies the degree of attack on the computer system. The probabilistic security policy re-posturing process **155** can increase or decrease the probability of an attack on the computer system based on the observation of a single key event, or a set of key events.

[0083] While the system and method have been particularly shown and described with references to configurations thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the embodiments disclosed herein encompassed by the appended claims. Accordingly, the present embodiments disclosed herein are not intended to be limited by the example configurations provided above.

1.-**20**. (canceled)

21. A computerized method, comprising:
at a client security agent:
initializing probability settings, based on information about known types of security attacks and representing an initial level of a security policy;
detecting an occurrence of a key event from a plurality of key events and collecting event data that represent effects caused by the occurrence of the key event;
selecting one or more first rules that take into consideration the effects caused by the occurrence of the key event, and applying the one or more first rules to the collected event data to compute one or more event result values;
in response to determining that the one or more event result values exceeded one or more corresponding threshold values, modifying the probability settings to increase the level of the security policy, applying one or more second rules to the modified probability settings and determining whether a new type of security attack has occurred;
wherein the method is performed by one or more processors.

22. The method of claim **21**, wherein the plurality of key events comprises any of:
a system call, a buffer overflow, an instance of downloaded content, an instance of CPU utilization, at least one network connection, a process exception, a system configuration modification, an instance of a new software program installation, an instance of a new service installation, a first time instance of a application invocation, an instance of mobile code execution, an instance of at least one root-kit detection, an instance of memory utilization, at least one transaction failure, and at least one loss of service.

23. The method of claim **21**, wherein applying the one or more first rules comprises assigning a weight to the key event.

24. The method of claim **21**, wherein modifying the probability settings comprises creating a Bayesian network model configured to detect a degree of attack, and denying an operation of a plurality of operations based, at least in part, on the modified probability settings.

25. The method of claim **21**, wherein detecting the occurrence of the key event comprises observing an order in which the key event occurred with respect to other events in the plurality of key events.

26. A apparatus, comprising:
one or more processors;
a memory, encoded with one or more sequences of instructions, which when executed by the one or more processors, cause the one or more processors to perform:
initializing probability settings, based on information about known types of security attacks and representing an initial level of a security policy;
detecting an occurrence of a key event from a plurality of key events and collecting event data that represent effects caused by the occurrence of the key event;
selecting one or more first rules that take into consideration the effects caused by the occurrence of the key event, and applying the one or more first rules to the collected event data to compute one or more event result values;
in response to determining that the one or more event result values exceeded one or more corresponding threshold values, modifying the probability settings to increase the

level of the security policy, applying one or more second rules to the modified probability settings and determining whether a new type of security attack has occurred.

27. The apparatus of claim **26**, wherein the plurality of key events comprises any of:

a system call, a buffer overflow, an instance of downloaded content, an instance of CPU utilization, at least one network connection, a process exception, a system configuration modification, an instance of a new software program installation, an instance of a new service installation, a first time instance of a application invocation, an instance of mobile code execution, an instance of at least one root-kit detection, an instance of memory utilization, at least one transaction failure, and at least one loss of service.

28. The apparatus of claim **26**, wherein the memory is further encoded with instructions, which when executed, cause the one or more processors to perform assigning a weight to the key event.

29. The apparatus of claim **26**, wherein the memory is further encoded with instructions, which when executed, cause the one or more processors to perform creating a Bayesian network model configured to detect a degree of attack, and denying an operation of a plurality of operations based, at least in part, on the modified probability settings.

30. The apparatus of claim **26**, wherein the memory is further encoded with instructions, which when executed, cause the one or more processors to perform observing an order in which the key event occurred with respect to other events in the plurality of key events.

31. A computer readable storage medium storing one or more sequences of instructions, which when executed by one or more processors, cause the one or more processors to perform:

initializing probability settings, based on information about known types of security attacks and representing an initial level of a security policy;

detecting an occurrence of a key event from a plurality of key events and collecting event data that represent effects caused by the occurrence of the key event;

selecting one or more first rules that take into consideration the effects caused by the occurrence of the key event, and applying the one or more first rules to the collected event data to compute one or more event result values;

in response to determining that the one or more event result values exceeded one or more corresponding threshold values, modifying the probability settings to increase the level of the security policy, applying one or more second rules to the modified probability settings and determining whether a new type of security attack has occurred.

32. The computer readable storage medium of claim **31**, wherein the plurality of key events comprises any of:

a system call, a buffer overflow, an instance of downloaded content, an instance of CPU utilization, at least one network connection, a process exception, a system configuration modification, an instance of a new software program installation, an instance of a new service installation, a first time instance of a application invocation, an instance of mobile code execution, an instance of at least one root-kit detection, an instance of memory utilization, at least one transaction failure, and at least one loss of service.

33. The computer readable storage medium of claim **31**, further comprising instructions, which when executed, cause assigning a weight to the key event.

34. The computer readable storage medium of claim **31**, further comprising instructions, which when executed, cause creating a Bayesian network model configured to detect a degree of attack, and denying an operation of a plurality of operations based, at least in part, on the modified probability settings.

35. The computer readable storage medium of claim **31**, further comprising instructions, which when executed, cause observing an order in which the key event occurred with respect to other events in the plurality of key events.

* * * * *